CHAPTER 4

RESULTS AND DISCUSSION

This research was intended to improve properties of heavy distillate fraction to be used as lubricating base oil by suitable refining processes. Heavy distillate which was obtained from Fang Refinery was a solid at room temperature because it contained high quantities of dissolved wax. The pour point of this distillate was 51 $^{\circ}$C. For proper lubricating of machinery in cool weather, this wax had to be removed to allow the oil to flow freely at all times to the bearings and also to prevent solidified wax from interfering mechanically with starting. The selected method for seperating wax was solvent dewaxing process. Methyl ethyl ketone, the most widely used solvent, was preferred because of its low wax solubility at dewaxing temperature and sufficiently low boiling point to facilitate removal from dewaxed oil. Dewaxing process started with melting of heavy distillate and then adding cooled methyl ethyl ketone with solvent/oil ratio 3:1. After chilling the mixture to the temperature of -15 $^{\circ}$C, the wax crystal was seperated by filtration and the oil fraction was recovered from the filtrate by simple distillation. The result from dewaxing of heavy distillate was shown in figure 4.1.

DEWAXING OF HEAVY DISTILLATE
BY METHYL ETHYL KETONE

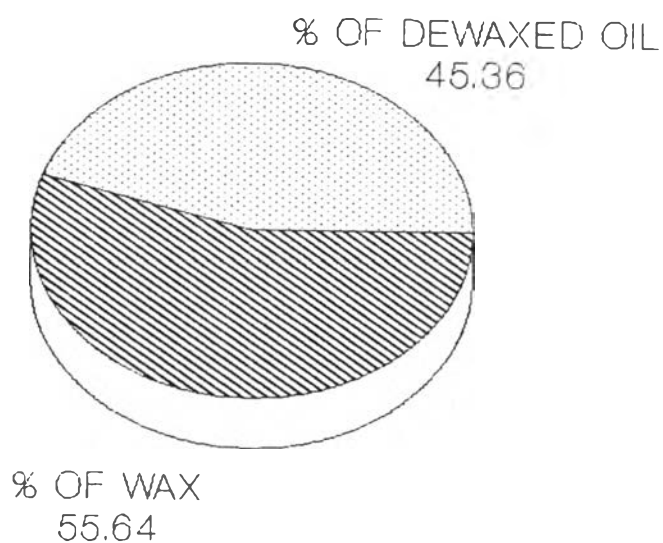% OF DEWAXED OIL
45.36

% OF WAX
55.64

Figure 4.1 The percents by weight of wax and oil seperated

by dewaxing process

From   figure   4.1, it showed that   methyl ethyl ketone

could   extract   up   to   54.64   % by weight of slack wax and

45.36 % by   weight of oil. Slack wax was a white crystal

solid and oil fraction was a black viscous liquid as shown in
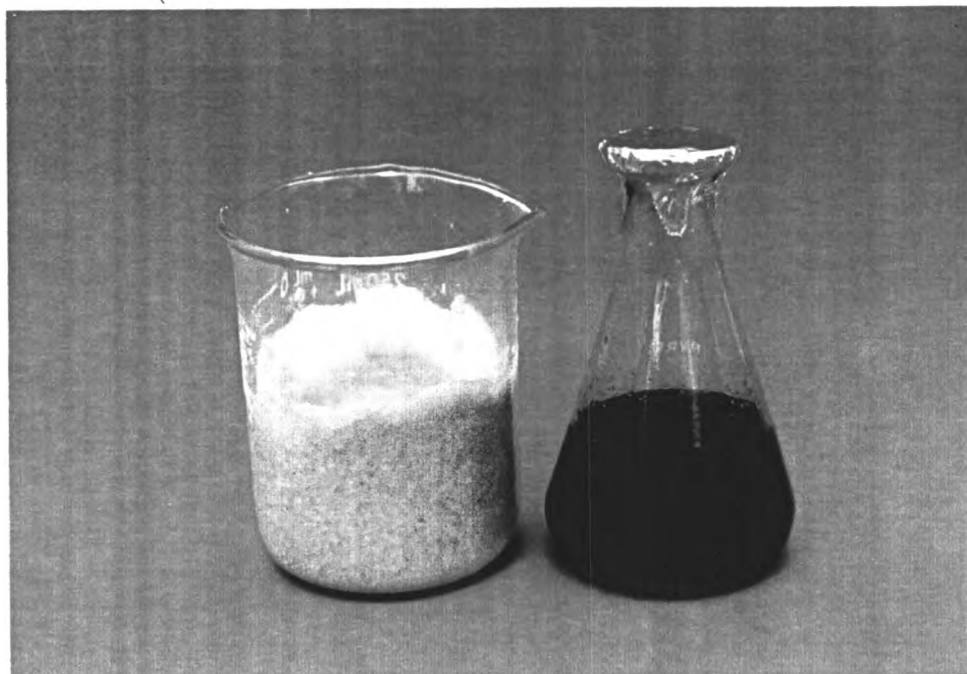
figure 4.2.

Figure 4.2 Wax and dewaxing oil

The physical and chemical properties of dewaxed oil were shown in table 4.1. The physical properties were as follow: color, pour point, kinematic viscosity, viscosity index and sulfur content. The aromatic carbon content ($\%C_a$), paraffinic carbon content ($\%C_p$) and naphthenic carbon content ($\%C_n$) were determined by C^{13}-NMR and the percentages of oxidative compounds were analyzed by thermogravimetric analyzer.

Table 4.1 The physical and chemical properties of dewaxed oil

Properties	
Physical:	
color,visual	>8
pour point ($^\circ$C)	2
kinematic viscosity	
@ 40 $^\circ$C, cSt	136.71
@ 100 $^\circ$C, cSt	10.15
viscosity index	22
sulfur, %wt	0.292
Chemical:	
% C_a	30.09
% C_p	35.62
% C_n	33.29
oxidation point ($^\circ$C)	288
oxidative compound	
(%wt)	17.35

From table 4.1, the results demonstrated that pour point of dewaxed oil was reduced from 51 $^\circ$C to 2 $^\circ$C. The sulfur content, aromatic carbon content, paraffinic carbon content, naphthenic carbon content and oxidative compounds were 0.292 %, 30.09 %, 35.62 %, 33.29 % and 17.35 % respectively. The color

was higher than 8.

Although dewaxing process improved pour point of dewaxed oil, the oil's color was still dark. The color of oil came from the color substances such as aromatic compounds, unsaturated compounds and sulfur compounds which were not removed by dewaxing process. The further refining process for improving the color of dewaxed oil was acid-clay treating process by using concentrated sulfuric acid and fuller's earth. Sulfuric acid was selected as it caused precipitation of asphaltenes and resins as well as the solution of color-bearing and sulfur compounds. The using of fuller's earth also bleached the oil and some certain impurities were absorbed on the clay's surface. Concentrated sulfuric acid (10 % by volume of oil) was vigourously mixed with dewaxed oil which was heated to 30 °C. Then distillated water (the same volume as acid) was added and the mixture was allowed to settle down at least 7 hours. After removal the acid sludge, the oil was neutralized with caustic soda. The clay treatment was then performed. The neutralized oil was mixed with fuller's earth (30 % by weight of oil) and the mixture was stirred for 45 minutes at temperature of 150 °C. The acid-clay treated oil and activated clay were seperated by filtration. The result from acid-clay treatment was shown in figure 4.3.

BLEACHING OF DEWAXED OIL
BY SULFURIC ACID AND FULLER'S EARTH

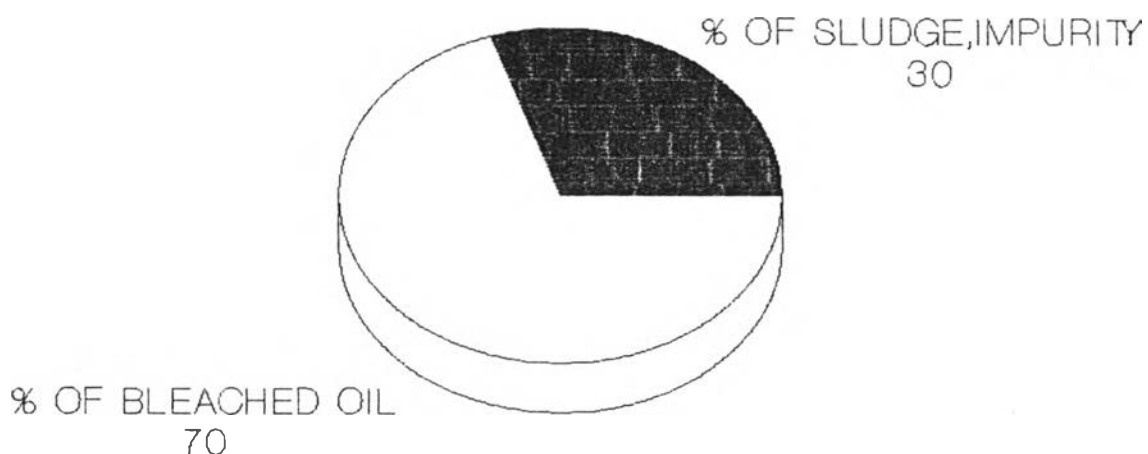% OF SLUDGE,IMPURITY
30

% OF BLEACHED OIL
70

Figure 4.3   The percents by weight of sludge and bleached oil

from acid-clay treated process

From   figure 4.3, it showed that this process could

remove   the sludges and impurities about   30 % by weight.

The oil obtained from this process was an orange viscous liquid
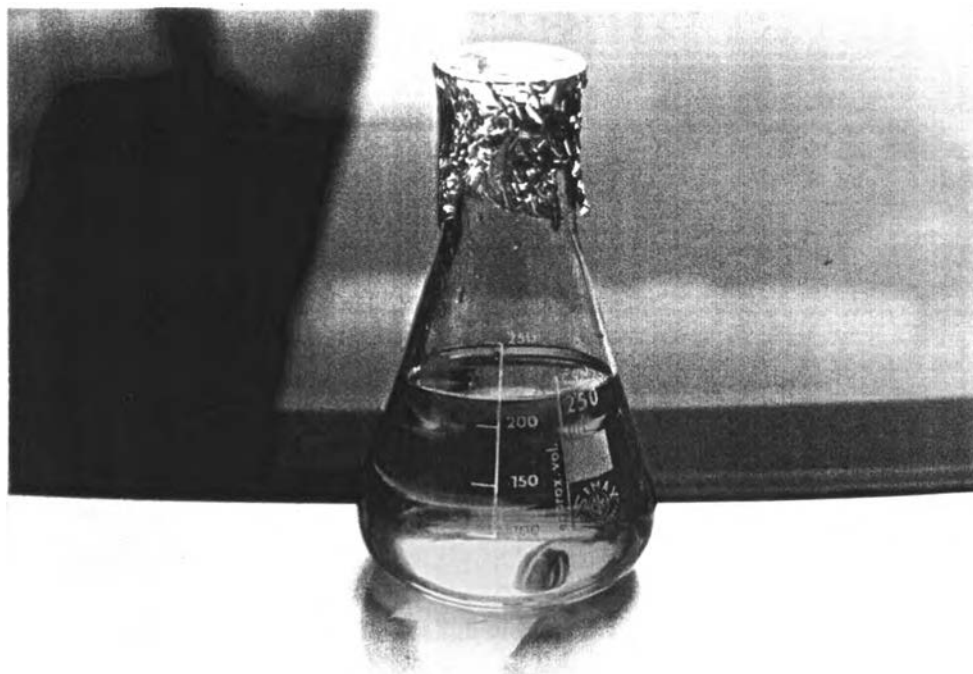
as shown in figure 4.4.

Figure 4.4 Acid-clayed treated oil

The physical and chemical properties of acid-clay treated oil were determined as shown in table 4.2. The physical properties were as follow: color, pour point, kinematic viscosity, viscosity index and sulfur content. The aromatic carbon content ($\%C_a$), paraffinic carbon content ($\%C_p$) and naphthenic carbon content ($\%C_n$) were determined by C^{13}-NMR and the percentages of oxidative compounds were analyzed by thermogravimetric analyzer.

Table 4.2 The physical and chemical properties of acid-clay
treated oil

Properties	
Physical:	
color,visual	2
pour point ($^\circ$C)	2
kinematic viscosity	
@ 40 $^\circ$C, cSt	103.34
@ 100 $^\circ$C, cSt	9.28
viscosity index	48
sulfur, %wt	0.141
Chemical:	
% C_a	25.98
% C_p	43.87
% C_n	30.15
oxidation point ($^\circ$C)	288
oxidative compound	
(%wt)	14.77

Comparing table 4.1 with table 4.2, the acid-clay
treated   oil 's color was reduced to 2   while the pour point was
still remained at 2 $^\circ$C. The viscosity index was increased from
22 to 48.   The aromatic carbon content and oxidative compound

were reduced from 30.09 % to 25.98 % and from 17.35 % to 14.77 % respectively.

Even though the two refining process-- dewaxing process and acid-clay treating process -- improved the pour point and color of oil, the acid-clay treated oil could not be used as lubricating base oil since its viscosity index was still low while the aromatic carbon content and oxidative compoud were still high. To improve the viscosity index and oxidation stability, the oil had to be finally refined through hydrotreatment.

Catalytic hydrotreating process could be effective for the saturation of aromatic compounds to naphthenic compounds as well as the reduction of sulfur. The required catalyst was a multifunctional catalyst comprised at least one Group VI metal, metal oxide and metal sulfide and at least one Group VIII metal, metal oxide and metal sulfide supported on a carrier. The acidic or cracking function was supplied by the catalyst support while the hydrogenation activity was supplied by the hydrogenation metal component. The advantage of this catalyst provided higher viscosity index and lower aromatic carbon content under lower condition. [17]

In this research, the acid-clay treated oil was treated with hydrotreated catalyst in a stirred autoclave batch reactor under hydrogen. The used catalyst contained 10% by weight of molybdenum trioxide (MoO_3) and 5% by weight of nickel oxide (NiO) supported on alumina type CS-303 which available in commercial from United Catalyst Inc.,. Molybdenum trioxide and

nickel oxide had high catalytic activity therefore they were widely used in hydrotreating process. The catalyst was prepared by dry impregnating method. The pore volume of this support was determined by using distilled water before impregnation. The pore volume of alumina support CS-303 was 0.2546 cm^3/g. Then the alumina support was impregnated with ammonium molybdate and nickel nitrate hexahydrate solution. This impregnation was difficult to achieve in one single wetting because a solution of both salts was stable only during a short time before a precipitate of nickel molybdate was formed. Accordingly, the impregnation was preferably carried out in two wetting seperated by drying overnight at 125 $^\circ$C and calcining with air at 450 $^\circ$C for one hour. The amount of molybdenum and nickel in the catalyst was analyzed by Inductively Coupled Plasma Emission Spectrometer as shown in table 4.3

Table 4.3   The percentages of molybdenum and nickel
            analyzed by ICP

%Mo/Al_2O_3	% Mo/Al_2O_3 analyzed by ICP	%Ni/Al_2O_3	%Ni/Al_2O_3 analyzed by ICP
10	9.01	5	4.33

From table 4.3, it showed that, the amount of prepared molybdenum trioxide and nickel oxide were 9.01 and 4.33 % by weight respectively.

Moreover, the catalyst activity was evaluated by hydrogenation of standard cyclohexene. Standard cyclohexene was treated with hydrogen in the present of prepared catalyst at 100 °C, 400 psig, about 2 hours. The hydrogenated product of cyclohexene was purified by usual manner and identified by Infrared Spectrophotometer. The IR spectrum of cyclohexene and hydrogenated product were shown in figure 4.5 and 4.6.

From figure 4.5, demonstrated the absorption band of cyclohexene unconjugated C=C double bond which appeared at wavenumber 1640 cm^{-1}. But in the hydrogenated product (figure 4.6), this absorption band disappeared which indicated that C=C double bond was hydrogenated. In accordance with the result from Inductive Couple Plasma and IR spectrum proved that the prepared catalyst had reactivity as the catalyst which was commercially available.
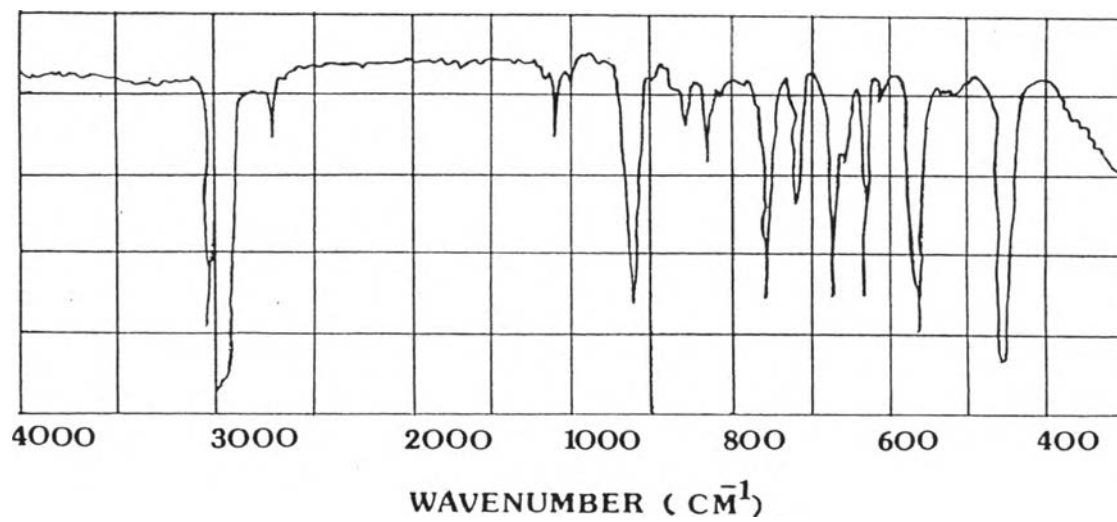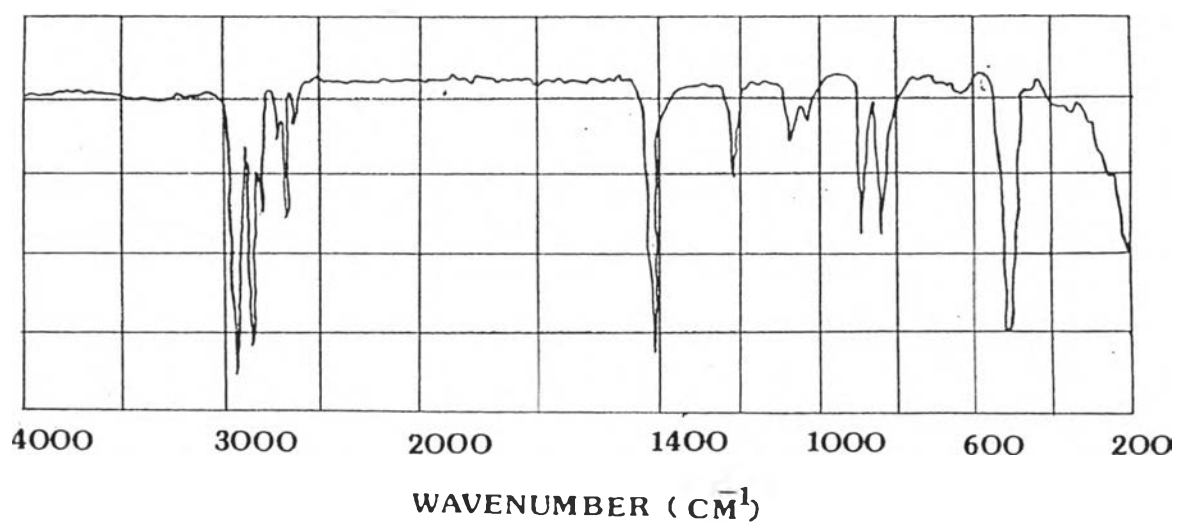
Figure 4.5 IR spectrum of cyclohexene

Figure 4.6 IR spectrum of cyclohexene after hydrogenation

This catalyst were optimizied for the hydrotreating of acid-clay treated oil by varying the following parameters: reaction temperature, catalyst concentration, reaction time and hydrogen partial pressure while fixing the percentages of molybdenum trioxide and nickel oxide in the catalyst.

The first concerned variable parameter in hydrotreating process was reaction temperature which was performed between 150 °C and 350°C. The hydrotreating reaction was carried out under hydrogen partial pressure of 529 psig and a reaction time of 2 hours, using a catalyst concentration of 3 % by weight of oil. The temperature was varied from 150, 200, 250, 300 and 350 °C.

While the temperature was increased, the pressure in the reactor was also increased. Where the temperature was 150, 200, 250, 300 and 350 °C, the total pressure was 286, 425, 705, 778, 899 psig respectively.

The result from hydrotreating of acid-clay treated oil which performed at various temperature of 150, 200, 250, 300, and 350 °C were shown in table 4.4. The effect of temperature on color, viscosity index, sulfur content, aromatic carbon content, paraffinic carbon content, naphthenic carbon content and oxidative compounds were shown in figure 4.7 - 4.11.

Table 4.4   Hydrotreating   of acid-clay treated oil at various
             reaction   temperature: cat.conc. 3% of oil, reaction
             time 2 hrs, hydrogen   partial pressure 529 psig,
             agitation speed 300 rpm

Properties	Base	Reaction Temperature ($^\circ$C)				
		150	200	250	300	350
Physical:						
Color, visual	2	3	3	2.5	1.5	1.5
Pour Point ($^\circ$C)	2	2	2	2	2	2
Viscosity						
@ 40 $^\circ$C, cSt	103.34	99.15	90.48	98.28	86.80	68.47
@ 100 $^\circ$C, cSt	9.28	9.11	8.68	9.21	8.56	7.61
Viscosity Index	48	50	52	55	56	64
Sulfur, %wt	0.141	0.135	0.114	0.106	0.077	0.018
Chemical:						
%C_a	25.98	20.12	19.74	19.55	18.41	15.83
%C_p	43.87	45.35	45.65	47.79	49.25	58.70
%C_n	30.15	34.53	34.61	32.66	32.34	31.47
Oxidation Point ($^\circ$C)	288	288	288	288	288	288
Oxidative cpd. (%wt)	14.77	14.59	14.32	14.20	13.84	13.01
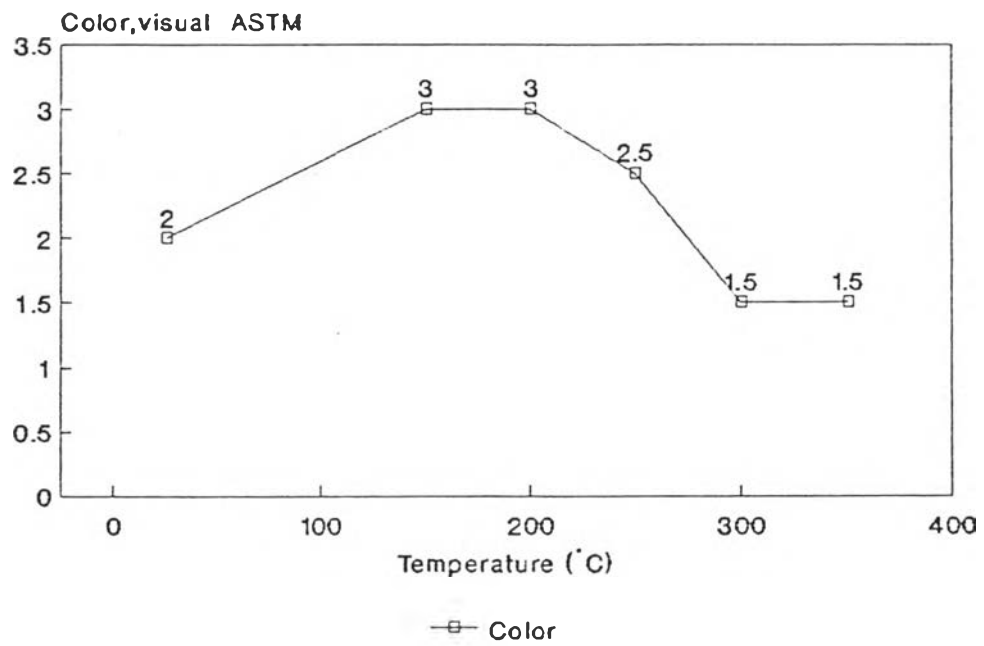
Figure 4.7 Effect of temperature on color
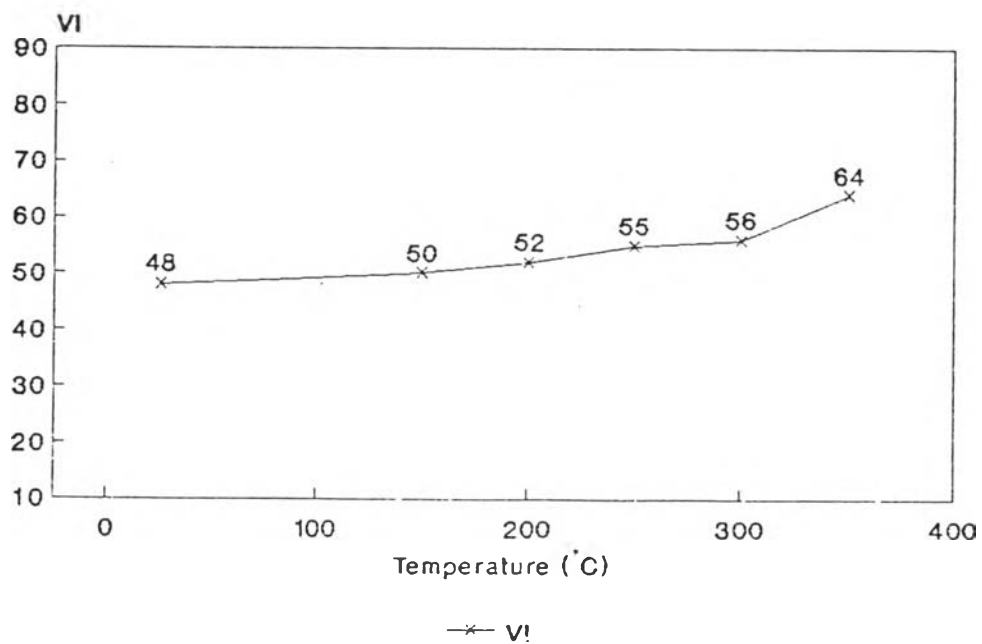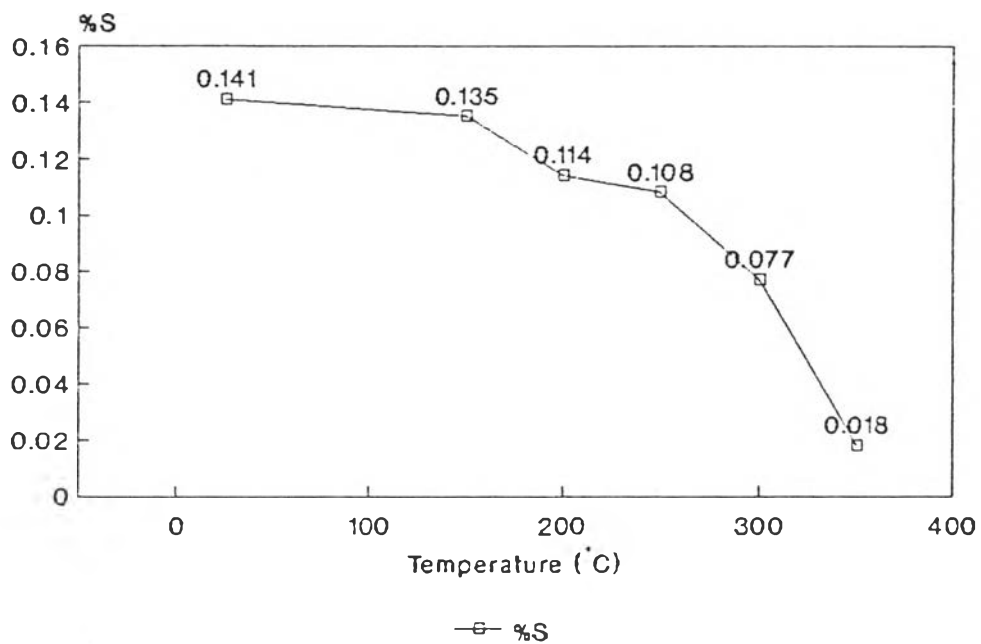

Figure 4.8 Effect of temperature on viscosity index

%S

0.16
0.14 — 0.141
0.135
0.12 — 0.114
0.108
0.1
0.08 — 0.077
0.06
0.04
0.02 — 0.018
0

0   100   200   300   400
Temperature (°C)

—□— %S

Figure 4.9   Effect of temperature on % sulfur

%C

70
60 — 58.7
50 — 43.87   45.35   45.65   47.79   49.25
40
34.53   34.61   32.66   32.34   31.47
30 — 30.15
25.98
20 — 20.12   19.74   19.55   18.41   15.83
10
0

0   100   200   300   400
Temperature (°C)

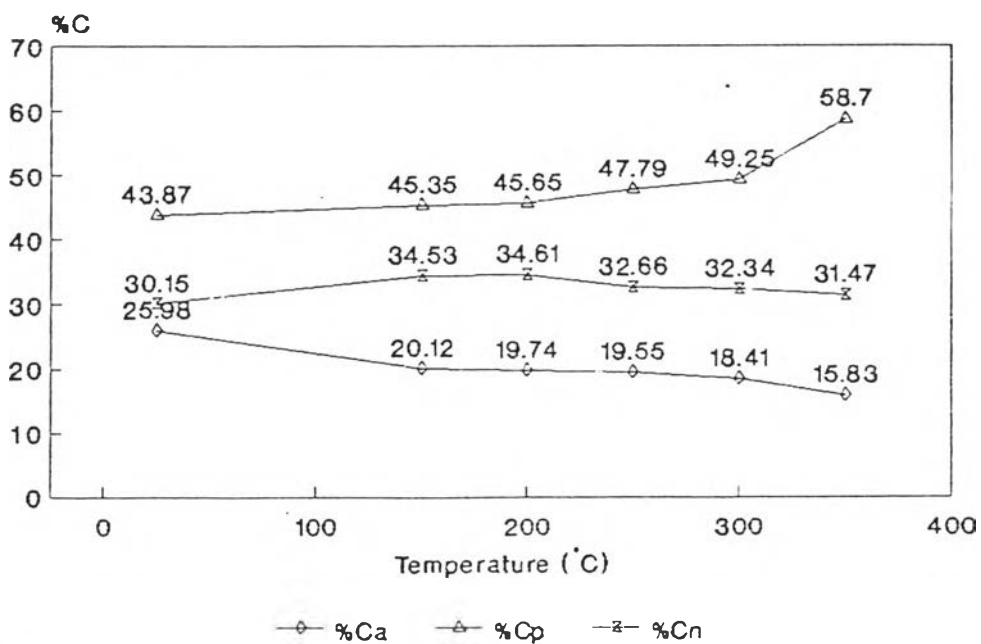—◇— %Ca   —△— %Cp   —ᴢ— %Cn

Figure 4.10   Effect of temperature on % carbon type
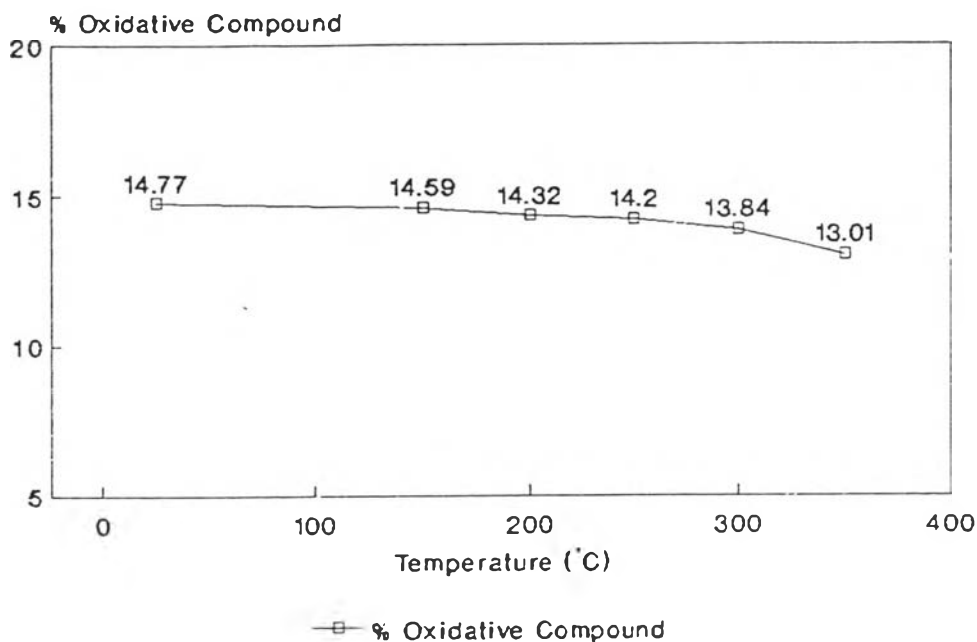
% Oxidative Compound

Figure 4.11   Effect of temperature on % oxidative compound

From this experiment, the viscosity index varied proportional with temperature. The evidences were shown in table 4.3 and figure 4.8 as viscosity index increased from 48 to 64 when the reaction was performed at 350 °C. On the other hand, the sulfur content, aromatic carbon content and oxidative compounds were decreased with an increase of temperature. From figure 4.9, sulfur content was reduced from 0.141 to 0.018 when the reaction was operated at 350 °C.

In the same way, the increasing temperature resulted in the decrease of aromatic carbon content as well as oxidative compounds as could be seen in figure 4.10 and figure 4.11. When the reaction temperature was 350 °C, aromatic carbon

content and oxidative compounds were reduced to 15.83 and 13.01 respectively. Like viscosity index, paraffinic carbon content and naphthenic carbon content were increased by the increasing temperature however this manner was limited at low temperature ranging from 150 °C to 200 °C. For the temperature higher than 250 °C, paraffinic carbon content was still increased while naphthenic carbon content was decreased with the increasing temperature as shown in figure 4.10.

The results showed that the effect of an increasing reaction temperature was to increase the rate of hydrogenation and desulphurization. Meanwhile, as the temperature was increased, those reactions involving cleavage of carbon-carbon bond, such as dealkylation, ring opening and chain breaking, increased which resulted in increasing of paraffinic carbon compound. On the other hand, when the temperature was as low as 150 °C to 200 °C, naphthenic carbon content was increased by an increase of temperature. But when the temperature was high, naphthenic carbon content was decreased since more ring opening were occured.

Within the range of the studied temperature, when temperature increased, more and more unsaturated linkage were hydrogenated. The evidence could be seen by the decrease in aromatic carbon content as well as oxidative compounds. The hydrotreated oils were .therefore more stable to oxidize and posses higher viscosity index.

According to the result in table 4.4, it was apparent

that the properties of hydrotreated oil which performed at 350 °C was the best. As a result, the optimum reaction temperature was 350 °C.

However, in the determination of optimum operating condition, other parameters were considered. Thus the further study looked for the suitable quantity of catalyst. The used catalyst concentration was varied from 1-5 %by weight of oil.

The hydrotreating of acid-clay treated oil at 350 °C, under hydrogen partial pressure of 529 psig(total pressure of 825 psig) and a reaction time of 2 hours was studied. The concentration of catalyst was varied to 1, 2, 3, 4, and 5 % by weight of oil.

The results from hydrotreating of acid-clay treated oils using different catalyst concentration of 1, 2, 3, 4, and 5 % by weight of oil were shown in table 4.5. The effect of catalyst concentration on color, viscosity index, sulfur content, aromatic carbon content, paraffinic carbon content, naphthenic carbon content and oxidative compounds were shown in figure 4.12 - 4.16.

Table 4.5   Hydrotreating of acid-clay treated oil using different
concentration of catalyst(% by weight of oil):
reaction temperature 350 °C, reaction time 2 hrs,
hydrogen partial pressure 529 psig, agitation speed
300 rpm

| Properties	Base	Concentration of catalyst (% by weight of oil)				
		1	2	3	4	5
Physical:						
Color,visual	2	1.5	1.5	1.5	1.5	1.5
Pour Point(°C)	2	2	2	2	2	2
Viscosity						
@ 40 °C, cSt	103.34	87.79	77.69	66.99	61.10	55.26
@ 100 °C, cSt	9.28	8.53	8.06	7.58	7.28	6.87
Viscosity index	48	53	58	67	71	71
Sulfur,%wt	0.141	0.108	0.062	0.053	0.035	0.014
Chemical:						
%C_a	25.98	20.87	18.60	15.96	14.76	13.30
%C_p	43.87	47.35	50.32	51.45	53.20	53.74
%C_n	30.15	30.78	31.08	32.59	32.04	32.96
Oxidation Point (°C)	288	288	288	288	288	288
Oxidative cpd. (%wt)	14.77	14.73	14.08	14.01	13.75	13.43
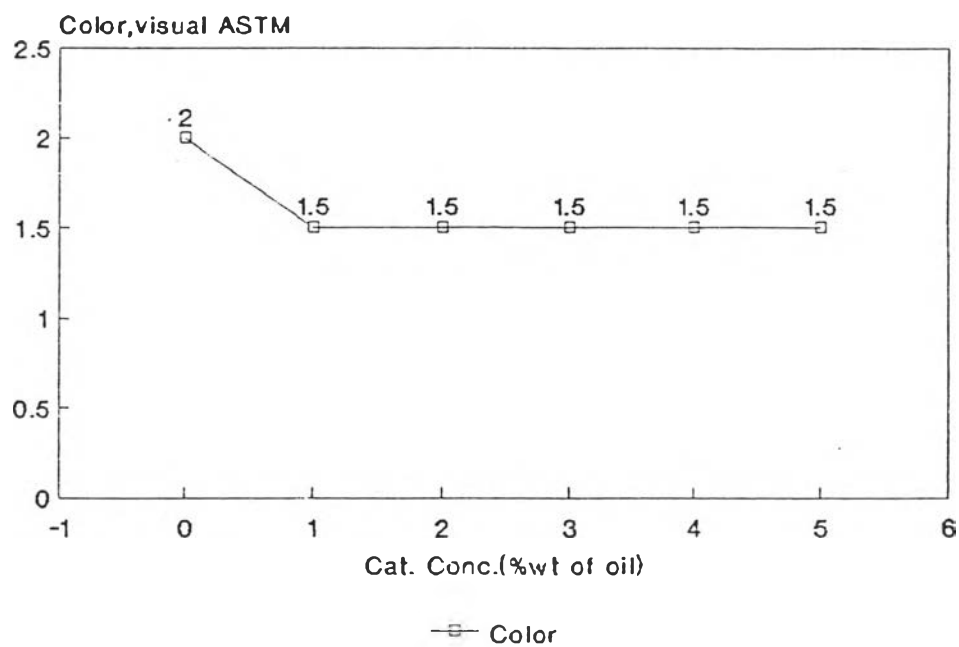
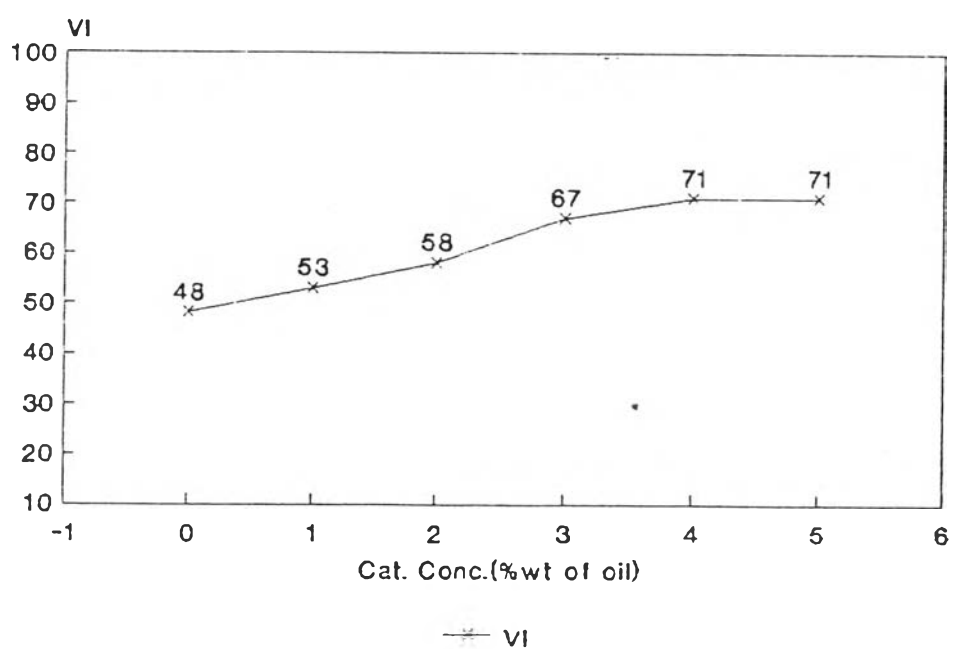Figure 4.12 Effect of catalyst concentration on color

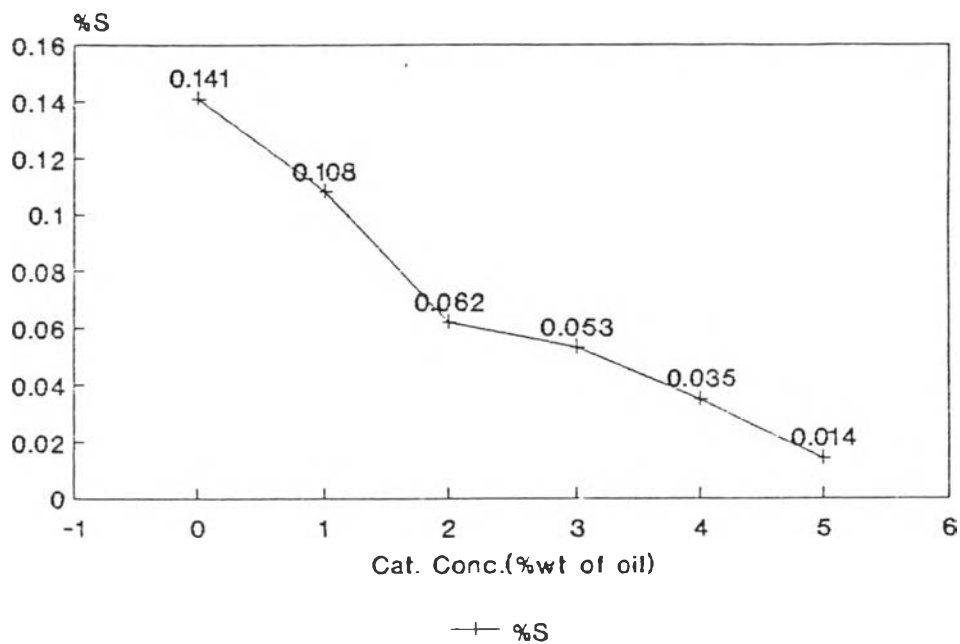Figure 4.13 Effect of catalyst concentration on viscosity

index

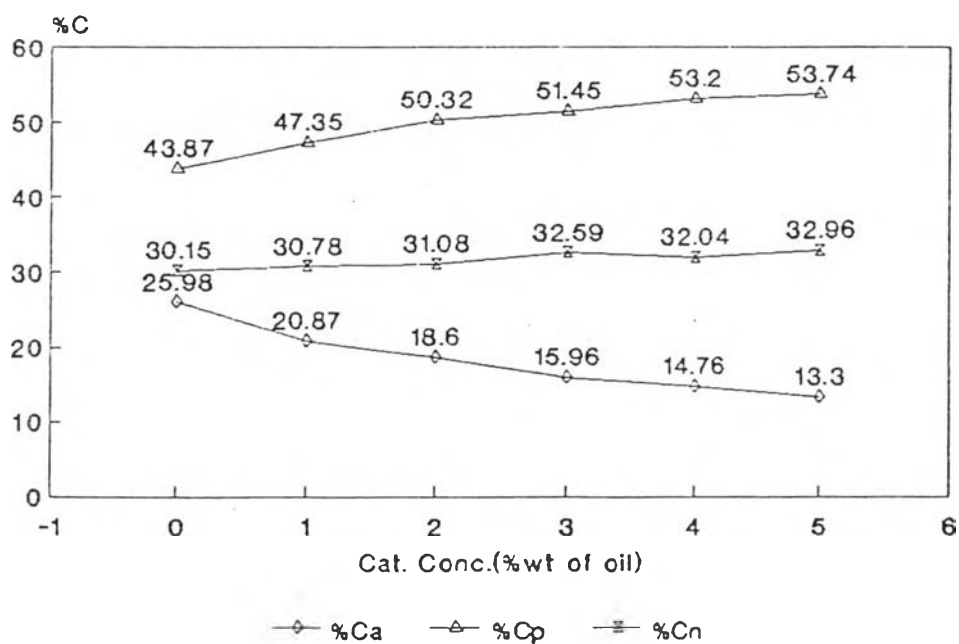Figure 4.14 Effect of catalyst concentration on % sulfur

Figure 4.15 Effect of catalyst concentration on % carbon type

% Oxidative Compound

14.77   14.73   14.08   14.01   13.75   13.43

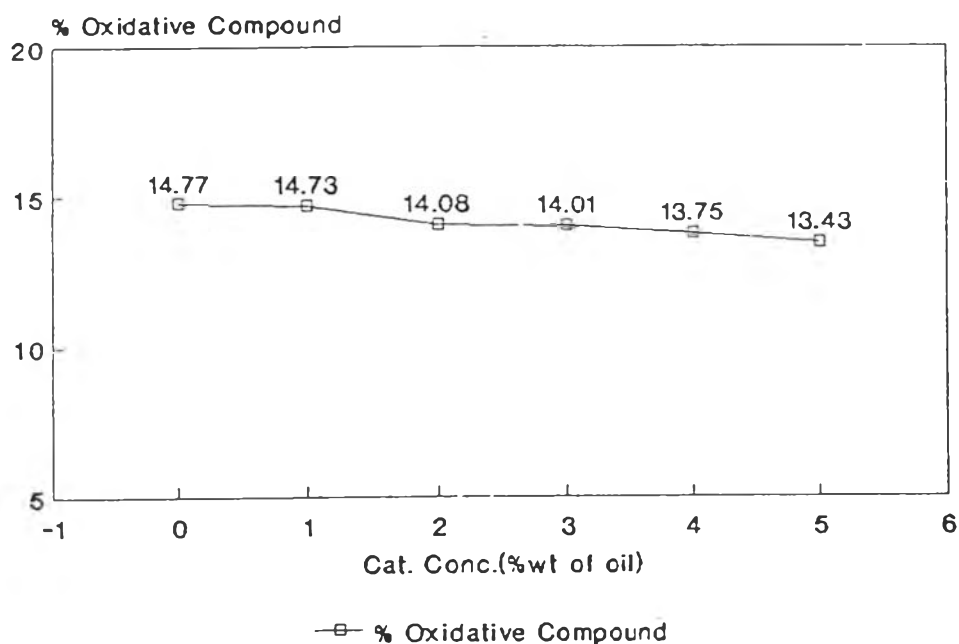Cat. Conc.(%wt of oil)

—□— % Oxidative Compound

Figure 4.16 Effect of catalyst concentration on % oxidative
compound

From this experiment, the color of hydrotreated base oil
was improved. From figure 4.12, the color of hydrotreated
base oil was decreased from 2 to 1.5 but remained constant
with an increase of catalyst concentration. On the other
hand, the sulfur content was decreased with increasing of
catalyst concentration. The result was shown in figure 4.14
as sulfur content would be rapidly reduced from 0.141 to 0.062
when the catalyst concentration was 2 % and slightly decreased
to 0.014 when the catalyst concentration was 5 % . The
adding of catalyst concentration would push the viscosity index
up. From figure 4.13, the viscosity index continued to increase
from 48 to 71 if the catalyst concentration was 4 %.

The chemical properties were also improved as the decrease in both aromatic carbon content and oxidative compounds, and the increase in both paraffinic carbon content and naphthenic carbon content could be expected once the catalyst concentration increased. The evidence was shown in figure 4.15 that at the 5 % of catalyst concentration, aromatic carbon content, paraffinic carbon content and naphthenic carbon content were 13.30 %, 53.74 % and 32.96 % respectively. The oxidative compounds were reduced from 14.77 % to 13.75 % at 4 % of catalyst concentration and to 13.43 % at 5 % of catalyst concentration (figure 4.16).

From this result, it could be seen that the increase in catalyst concentration did not effect the color of hydrotreated base oil but did remove more sulfur and increase higher viscosity index. Keeping other parameters constant increasing catalyst concentration would increase the active site of the catalyst and also increase the rate of reaction. From this reason, the increasing of catalyst concentration brought the viscosity index higher while pulled down the aromatic carbon content as well as oxidative compounds. However, the quantity of catalyst to be used must appropriate depend on the properties of feedstock.

From this study, during the variation of catalyst concentration in hydrotreating process, the decision was made to select of 4 % as the optimum concentration due to economic aspect. At this concentration gave the oil with color, viscosity index, sulfur content, aromatic carbon content and oxidative

compounds were 2, 77, 0.035 %, 14.76 % and 13.75 % respectively.

As previously mentioned, the viscosity index of hydrotreated oil was 77 at 4 % and 5 % of catalyst concentration while the reaction time was constant at 2 hours. Thus the reaction time was the next interested parameter.

The hydrotreating of acid-clay treated oil at 350 $^\circ$C, under hydrogen partial pressure of 529 psig(tatal pressure of 811 psig) and 4 % of catalyst concentration was studied. The reaction time was varied from 1,1.5, 2, 2.5, and 3 hours.

The results from hydrotreating of acid-clay treated oil when performed at various reaction time of 1, 1.5, 2, 2.5 and 3 hours were shown in table 4.6. The effect of time on color, viscosity index, sulfur content, aromatic carbon content, naphthenic carbon content, paraffinic carbon content and oxidative compound were determined to give the results that showed in figure 4.17-4.21.

Table 4.6   Hydrotreating of acid-clay treated oil at various reaction time: reaction temperature 350 °C, cat. conc. 4% oil, hydrogen partial pressure 529 psig, agitation speed 300 rpm

| Properties	Base	Reaction Time (hrs)				
		1	1.5	2	2.5	3
Physical:						
Color,visual	2	1.5	1.5	1.5	1.5	1.5
Pour Point(°C)	2	2	2	2	2	2
Viscosity						
@ 40 °C, cSt	103.34	80.40	65.94	62.26	54.63	40.19
@ 100 °C, cSt	9.28	8.31	7.45	7.37	6.93	5.77
Viscosity Index	48	61	64	71	77	77
Sulfur,%wt	0.141	0.036	0.032	0.030	0.031	0.047
Chemical:						
$\%C_a$	25.98	15.73	15.28	13.66	11.09	10.07
$\%C_p$	43.87	50.81	53.38	54.68	56.51	57.41
$\%C_n$	30.15	30.46	31.34	31.66	32.40	32.52
Oxidation Point (°C)	288	288	288	288	288	288
Oxidative cpd. (%wt)	14.77	14.59	14.14	13.72	12.91	12.07
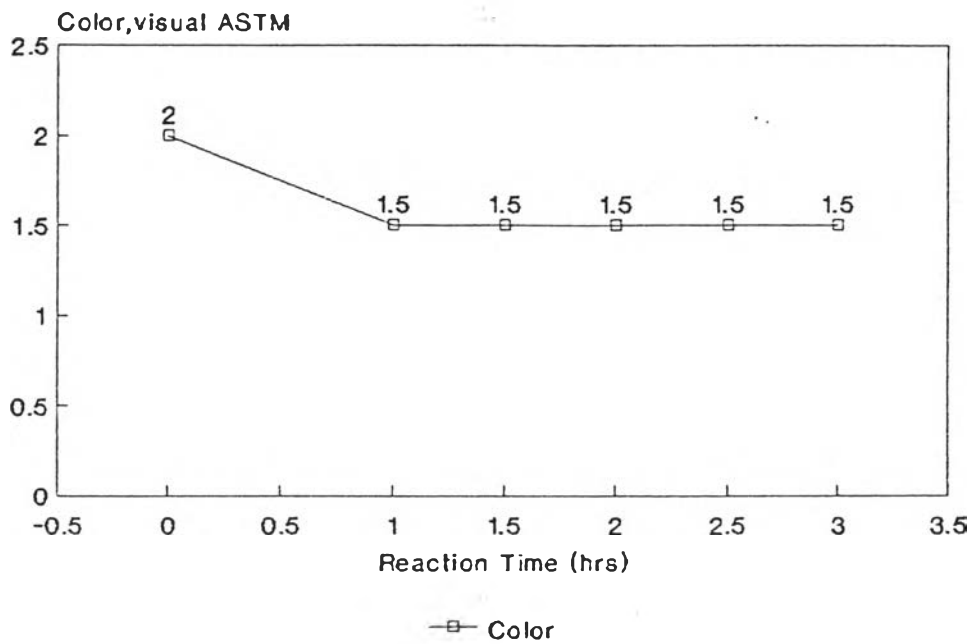
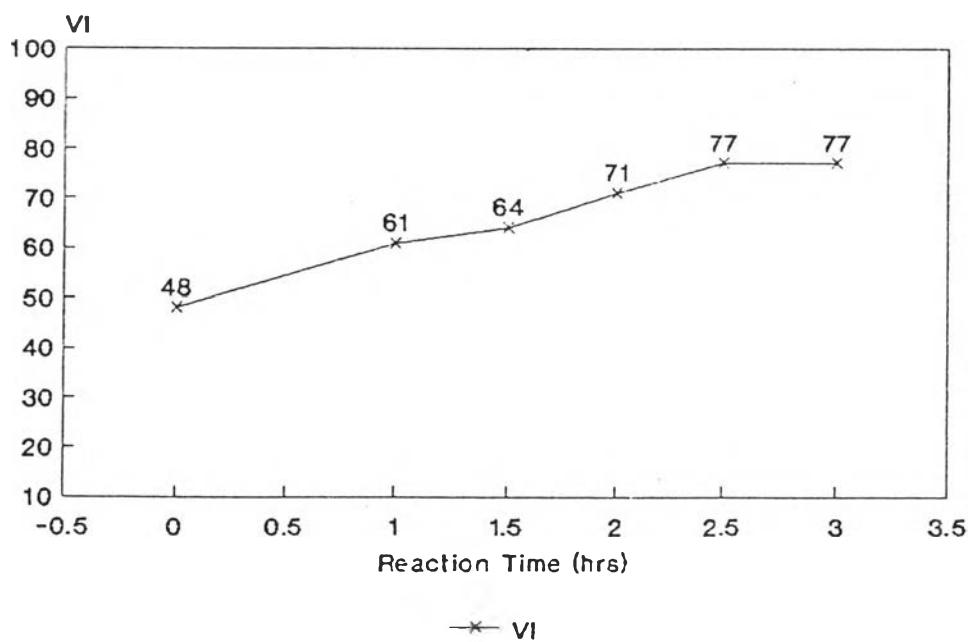Figure 4.17 Effect of time on color
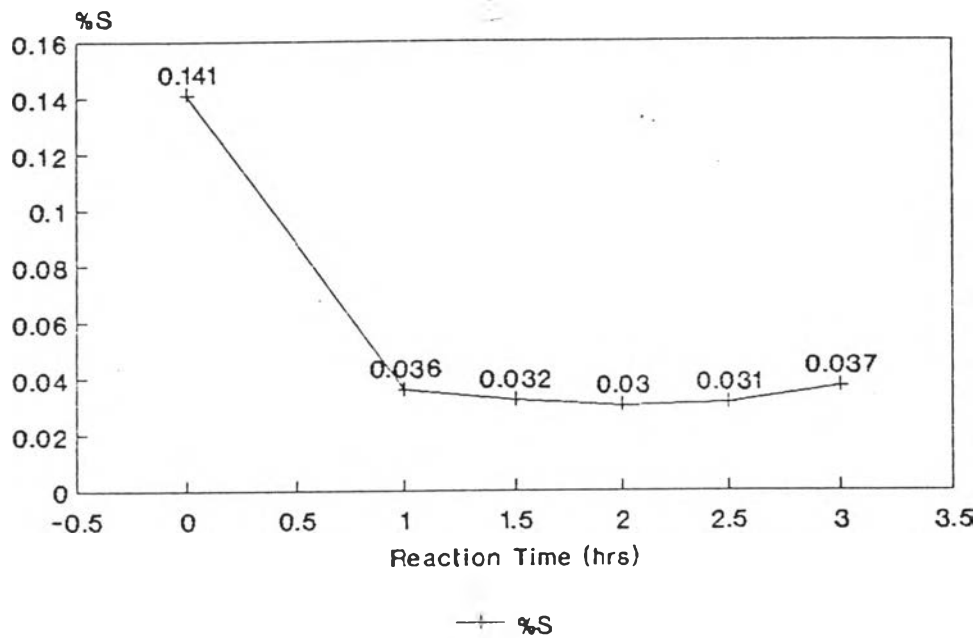

Figure 4.18 Effect of time on viscosity index

Figure 4.19 Effect of time on % sulfur

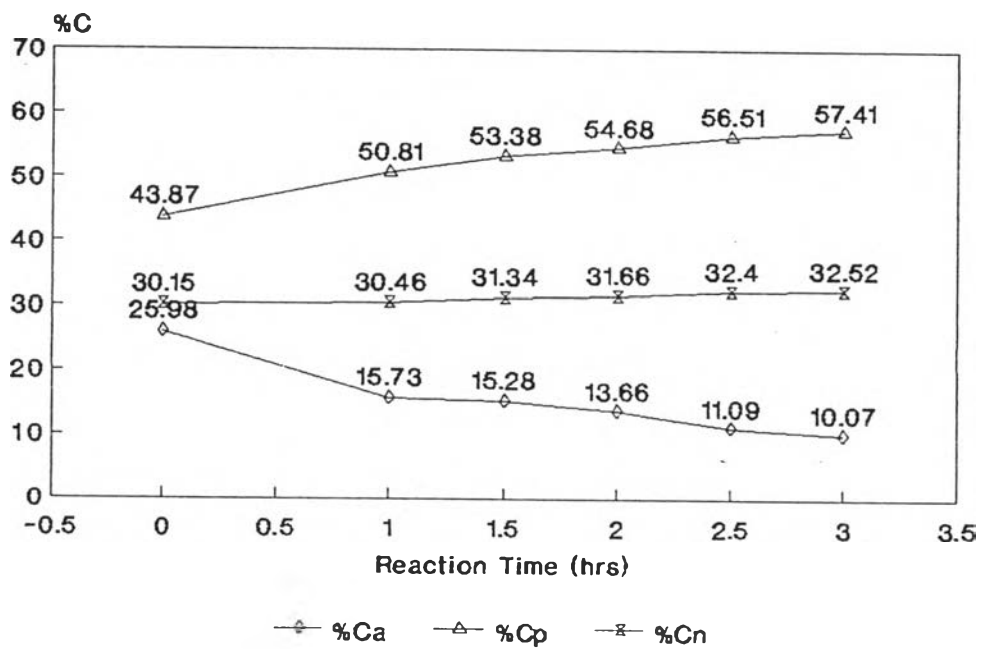Figure 4.20 Effect of time on % carbon type
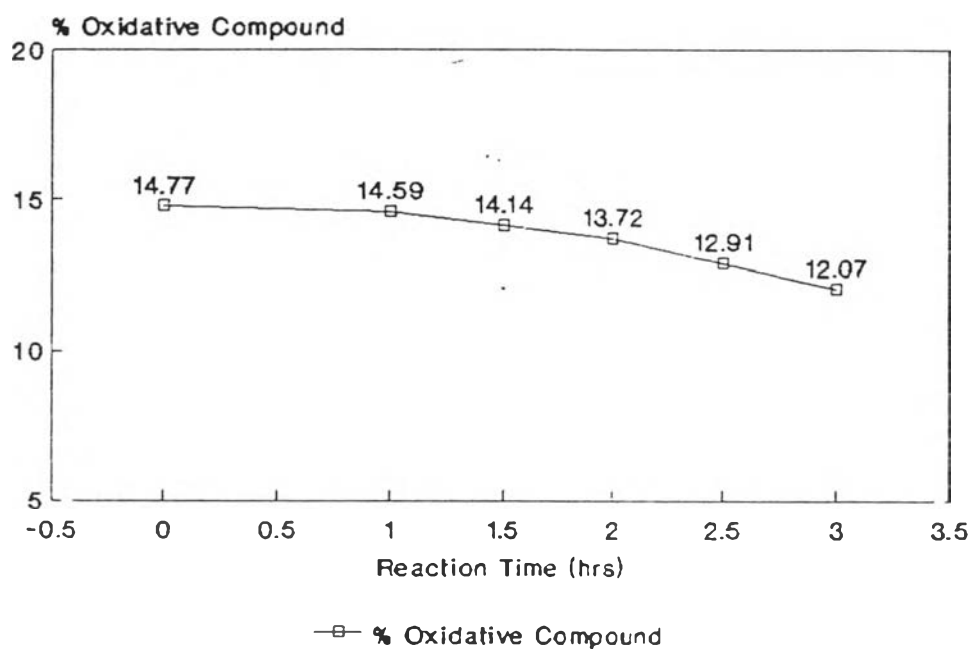
% Oxidative Compound

Figure 4.21 Effect of catalyst concentration on % oxidative
compound

From this experiment, while the longer the reaction
time was spent, the higher the viscosity index was resulted.
As could be seen in figure 4.18 that the acid-clay treated oil,
when hydrotreated with longer time, the viscosity index was
increased from 48 to 77, the point at which the period of
2.5 and 3 hours were spent. On the other hand, the passage of
time would lessen the color as well as sulfur content. From
figure 4.17, the color was decreased from 2.0 to 1.5 and
remained constant. The sulfur content was also reduced from
0.141 to 0.036 when the reaction time was one hour (figure 4.19).

Figure 4.20 showed the relationship between the
percentages of carbon type and the period of time spending.

As could be seen that the lengthen of time would increase paraffinic carbon content and naphthenic carbon content but decrease aromatic carbon content. The evidence was seen as when the reaction time was 3 hours, the aromatic carbon content, naphthenic carbon content and paraffinic carbon content were 10.07 %, 32.52 %, and 57.41 % respectively. In accordance with the quantity of aromatic compounds, the longer the time, the lesser the oxidative compounds.

The conclusion could be attained following the experimental results as the lenghten of time had no effect on any improvement neither in the color nor the sulfur of hydrotreated oil. However the lengthen the time from one hour to 3 hours would increase hydrotreating reaction since the viscosity index was increased while aromatic carbon content as well as oxidative compounds were decreased.

The paraffinic carbon content and naphthenic carbon content were increased when the reaction time was passed. Nevertheless, when the time was beyond this limit, more cracking were expected and thus the yield of lubricating base oil were reduced.

From this experimental results indicated that the optimum reaction time was apparently at 2.5 hours.

The last concerned variable parameter was the pressure of the process which was controlled by the hydrogen partial pressure. This step was interested to study the effect of the amount of hydrogen.

The hydrotreating of acid-clay treated oil was carried

out at 350 °C for 2.5 hours, using a catalyst concentration of 4 % by weight of oil. The hydrogen partial pressure was varied from 129, 229, 329, 429 and 529 psig. The total pressure at the reaction temperature was 280, 380, 599, 688, 819 psig.

The results from hydrotreating of acid-clay treated oils which conducted at various hydrogen partial pressure of 129, 229, 329, 429, and 529 psig were shown in table 4.7. The effects of hydrogen partial pressure on color, viscosity index, sulfur content, aromatic carbon content, paraffinic carbon content, naphthenic carbon content and oxidative compounds were shown in figure 4.22-4.26.

Table 4.7 Hydrotreating of acid-clay treated oil at different hydrogen partial pressure : reaction temperature 350 °C, cat. conc. 4% of oil, reaction time 2.5 hrs, Hydrogen partial pressure 529 psig, agitation speed 300 rpm

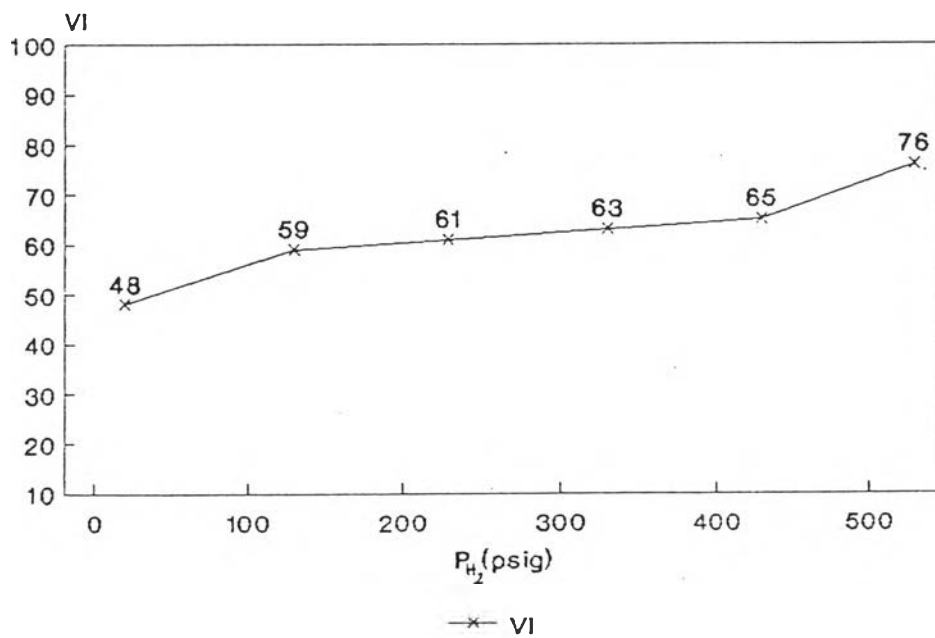| Properties	Base	Hydrogen Partial Pressure (psig)				
		129	229	329	429	529
Physical:						
Color,visual	2	1.5	1.5	1.5	1.5	1.5
Pour Point(°C)	2	2	2	2	2	2
Viscosity						
@ 40 °C, cSt	103.34	61.73	69.39	68.88	61.64	61.94
@ 100 °C, cSt	9.28	7.08	7.60	7.62	7.19	7.47
Viscosity Index	48	59	61	63	65	76
Sulfur,%wt	0.141	0.073	0.033	0.024	0.005	0.006
Chemical:						
$\%C_a$	25.98	18.36	17.66	16.95	15.61	13.44
$\%C_p$	43.87	51.41	51.45	51.35	52.01	53.91
$\%C_n$	30.15	30.50	30.89	31.70	32.38	32.65
Oxidation Point (°C)	288	288	288	288	288	288
Oxidative cpd. (%wt)	14.77	14.11	13.49	13.21	12.49	11.90
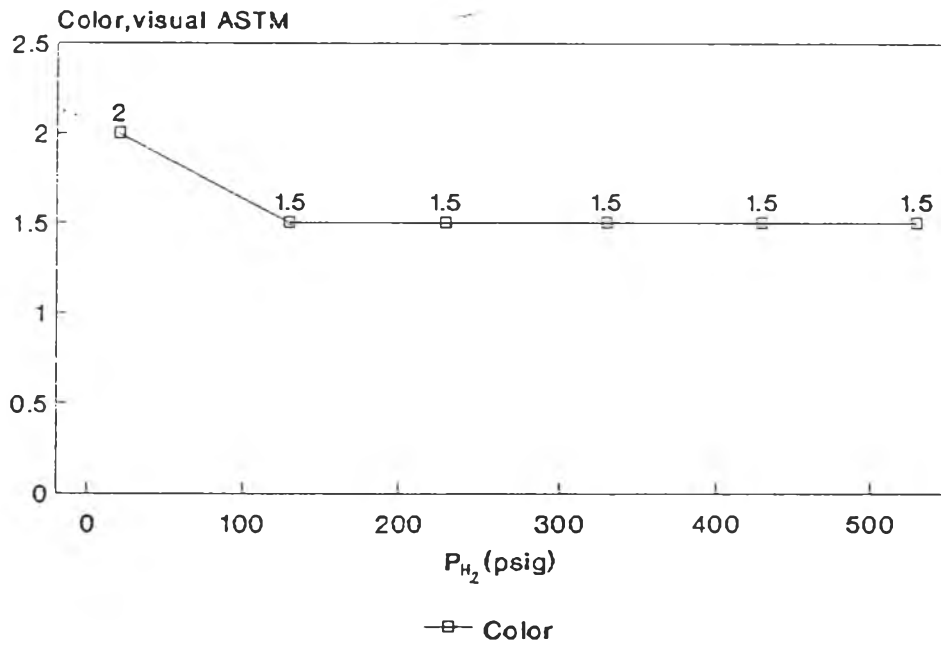
Figure 4.22 Effect of hydrogen partial pressure on color

Figure 4.23 Effect of hydrogen partial pressure on
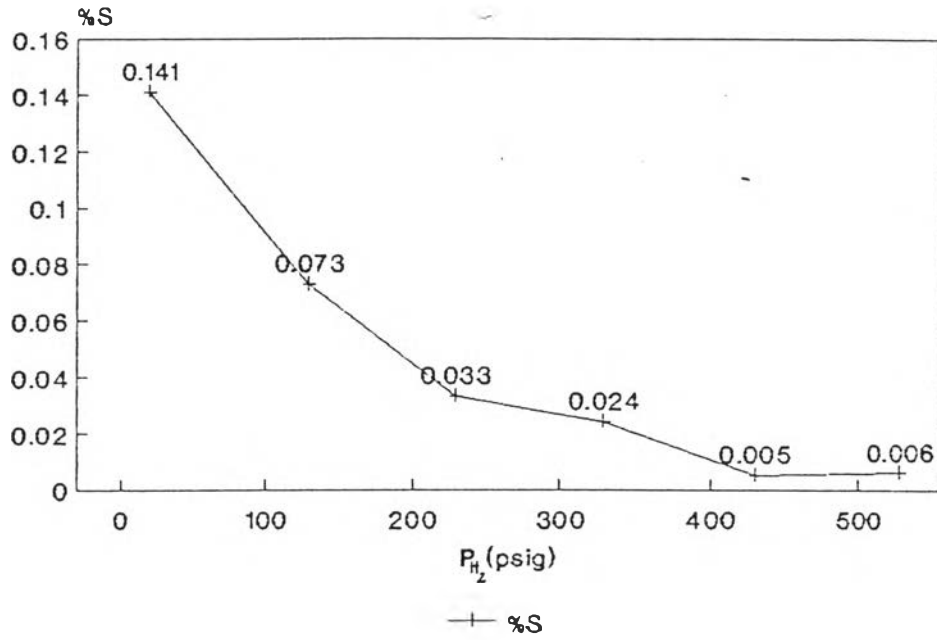viscosity index

%S

0.16
0.14 0.141
0.12
0.1
0.08   0.073
0.06
0.04   0.033
0.02   0.024
0   0.005   0.006
     0   100   200   300   400   500

P_{H_2}(psig)

—+— %S

Figure 4.24 Effect of hydrogen partial pressure on % sulfur

%C

70
60
53.91
50 43.87 51.14 51.45 51.35 52.01
40
30 30.15 30.5 30.89 31.7 32.38 32.65
    25.98
20   18.36 17.66 16.95 15.61
10   13.44
0
   0   100   200   300   400   500

P_{H_2}(psig)

—◇— %Ca   —△— %Cp   —✕— %Cn
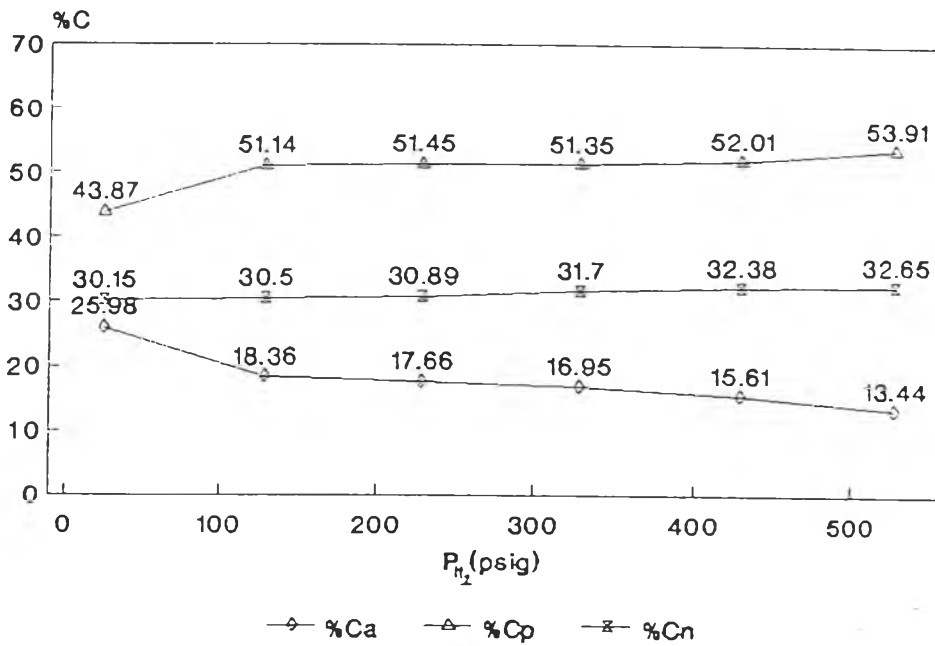
Figure 4.25 Effect of hydrogen partial pressure on
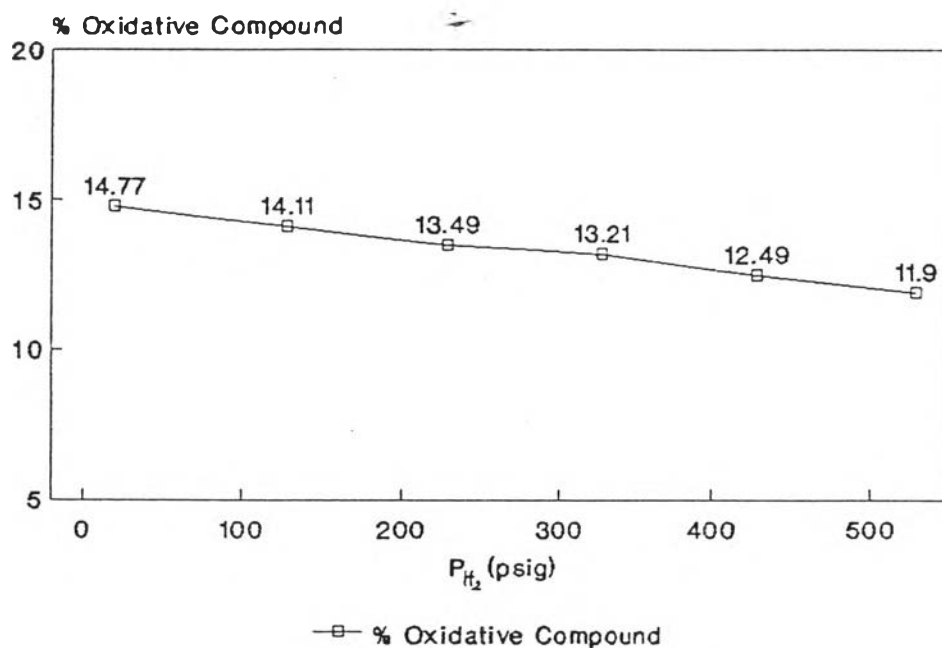% carbon type

% Oxidative Compound

Figure 4.26   Effect of hydrogen partial pressure on % oxidative compound

The increasing in hydrogen partial pressure increased the viscosity index of hydrotreated oil. From table 4.6 and figure 4.23, it was apparent that when the hydrogen partial pressure was 529 psig, the viscosity index was increased rapidly from 48 to 76. But at the lower hydrogen partial pressure, the viscosity index was scarcely changed, the color and sulfur content of hydrotreated oil were minimized. From figure 4.22, the color was decreased from 2 to 1.5 when hydrogen partial pressure was 129 psig but remained constant even when the hydrogen partial pressure was continued to rise. Figure 4.24 showed that the sulfur content sharply decreased from 0.141 to 0.033 when the hydrogen partial pressure was

229 psig. The sulfur content continued to decrease but to a lesser extent when the hydrogen partial pressure was more than 229 psig.

In term of the stability of oil, the higher the hydrogen partial pressure was, the lower the oxidative compounds and the aromatic compound were. From figure 4.25 and 4.26 , when the hydrogen partial pressure was 529 psig, oxidative compounds and aromatic compounds were 11.90 % and 13.44 % respectively.

It was proper to conclude that the increase of hydrogen partial pressure improved properties of hydrotreated oils since the color, sulfur content and oxidation stability were reduced while the viscosity index was increased. From this result, it could be described that increasing of hydrogen partial pressure increased the degree of hydrodesulfurization , hydrogenation of aromatics and coke precursors.

From this experimental results, indicated that the optimum hydrogen partial pressure was 529 psig.

In conclusion, the best condition for hydrotreating of acid-clay treated oil using 10 % of molybdenum trioxide and 5 % of nickel oxide on alumina as catalyst were a temperature of 350 °C, a hydrogen partial pressure of 529 psig and a catalyst concentration of 4 % by weight of oil at 2.5 hours. The properties of acid-clay treated oil were improved after hydrotreating. The color, sulfur content, viscosity index, aromatic carbon content and oxidative compounds of hydrotreated oil performed under the optimum operating

condition   were   1.5,   0.031%,   77,11.07%,   and   12.91%
respectively.

Table A1 showed the physical properties of imported
lubricatimg base oils from various sources. The comparison
between these properties and the properties of hydrotreated oil
found that hydrotreated oil was relatively low in viscosity index
and the percentages of sulfur but was relatively high in pour
point.

Eventhough the hydrotreated oil is not suitable in the
automotive uses as it has low viscosity index, the oil is usable
as a lubricating base oil in industrial engines especially as
turbine oil and hydralic oil where the high viscosity index is
not demanded.

Still, in the production of any types of lubricating oils
whether in engine service or industrial service, the blending of
several grades of base oils and additives is required in order to
improve the overall properties. The choices of the add-in are
depending upon the application.